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The Study of the Improvement of Mechanical Performance of Asphalt Modified by the Optimization of Mixing Time of EVA Bitumen

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Abstract. To improve the performances of a bitumen, the mixing time of bitumen-EVA is studied using two contents of EVA (3 and 5%). For the study analytical and chemical tests are carried out such as penetrability, softening point, ductility, FTIR, DSC, MEB and the storage stability. The aim of this work is to change and optimize the formula of the sample of EVA, which are not conform with the Algerian standards. This work showed that the mixing time is function of the content polymer. The mixing time has a strong effect on the properties; in fact it has improved the mechanical characteristics of the bituminous. Also, the mechanical tests showed that the permanent deformations and the indirect tensile strength at the temperatures of service resistances are improved.

Keywords: EVA-Bitumens, Mixing time, Characterisation, Behaviour, Bituminous concrete.
PACS: 81.70.-q

INTRODUCTION

The bitumen is an element of the bituminous concrete of the wearing course of the flexible pavements. The bitumen binder must be rather flexible at weak temperatures of service to prevent cracking and to be sufficiently rigid to prevent rutting at high temperature of service [1]. The modification of the bituminous mix by polymers [1-5] offers a solution to correct this problem of stability of the bituminous concrete [6]. The EVA (ethylene and vinyl Acetate) has been a plastomer used for the modification of the bitumen binders for more than 30 years [7] in order to improving the handiness of the binder during construction and its resistance to the deformations of services [4]. The incorporation of this modier with the bitumens involves a modification which is function of the bitumen itself (characteristic physics, chemical composition), of copolymer (nature of the comonomer, content of comonomer, molecular mass), of its content [8,9] and also of the manufacturing process (time, temperature and rate of malaxation). In this study, the mixing time of the bitumens-EVA is given. Its optimization is based on the improvement of the mechanical performances of a bituminous concrete formula (0/14) of poor characteristics.

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MATERIALS AND EXPERIMENTAL METHODS

The bitumen used for this study is AC 40-50. Tests of usual characterization were carried out. The value of the softenning point (50°C) is relatively low. Knowing that in Algeria the temperature of 50°C is easily reached in the roadway this will increase certainly the risks of rutting in hot time.

The EVA recommended for a road use must have a content vinyl acetate ranging between 18 and 33% [8,10]. The EVA choosed for this study is a semicrystalline plastomer containing 18% of vinyl acetate with an index of fluidity of 2,7 g/10 min. It is presented in the form of white lenses (2 to 5 mms in diameter). A Differential Thermal Analysis (DTA) was carried out on polymer. The melting point of the EVA is of 68,1°C. The TGA analysis shows that it is no notable loss of weight on the interval 170-180°C which corresponds to the mixing temperature of the modified bitumen. If one takes as criterion of index of stability thermal a loss of 5% of the initial weight [11].

The EVA-bitumens were manufactured at a temperature of 175°C with a rate of shearing of 600 tr/min. The mixing time was varied between 30min and 4h (30min, 1h, 1h30min, 2h, 3h and 4h). Two percentages are adopted for modier 3% and 5% of the optimal bitumen weight. The choice of these percentages is based on former studies [12].

Three granular fractions are retained for the formulation of the asphaltic concrete. They come from the careers of the north of Algeria. The sand is calcareous and the gravels are basalt.

The dispersion of EVA in the bitumen was observed by optical microscopy.

The storage stability was estimated for the modified mixtures: The bitumen-polymer mixture is versed in a cylindrical aluminium tube (32mm of diameter and 160mm height) in driving position, then placed in a drying oven at a temperature of 143 ± 5°C during 48 hours, after cooling with the room temperature, the tube is cut in three equal parts. The softening point values of the parts higher and lower are measured. The mixture is stable If the difference between the values does not exceed 2,5°C then.

In this investigation the Hot Mixtures Asphalts were characterised through Marshall Test. The dimensions of the cylindrical specimens are 101.6 mm diameter by 63.5 mm height. The samples were compacted at 150°C with 50 blows per face then stored at ambient temperature for one day. Before performing Marshall tests, the compactness is measured after which, standard specimens were immersed in water at 60°C for 35 min and then loaded to failure using curved steel loading plates along a diameter at a constant rate of compression of 51 mm/min.

The Marshall stability value (in kN) corresponds to the maximum force recorded during test while the flow (in mm) is the deformation noted at the maximum force. The ratio of stability to flow, called Marshall Quotient "MQ (in kN/mm)" is calculated to give indication of the mix stiffness [13].

The indirect tensile strength test is also carried out. It makes to determine the indirect tensile strength (splitting) of a cylindrical sample of bituminous concrete. The cylindrical sample to submit for testing 25 °C, and is subjected to a diametrical load along the axis of the cylinder at a constant speed of displacement of 50 mm/min. The indirect tensile strength is the maximum tensile stress obtained by the maximum loading to the rupture and the dimensions of the sample.

The optimal bitumen content is 5,8%. The characteristics obtained with AC 40-50 do not answer the Algerian specifications on the asphaltic concretes 0/14. The improvement of this mixture is thus necessary.

INTERPRETATION AND DISCUSSION

Modification of the Bitumen

Figure 1 shows the penetrability and softening point measurements according to mixing time. The evolution of the physical properties of the modified bitumens is characterised by a reduction in the penetrability and an increase of the softening point, thus decreasing thermal susceptibility. In addition, the consistency of the binders with 5% is harder than that of binders with 3%. In addition, the consistency of the binders with 5% is harder than that of binders with 3%.

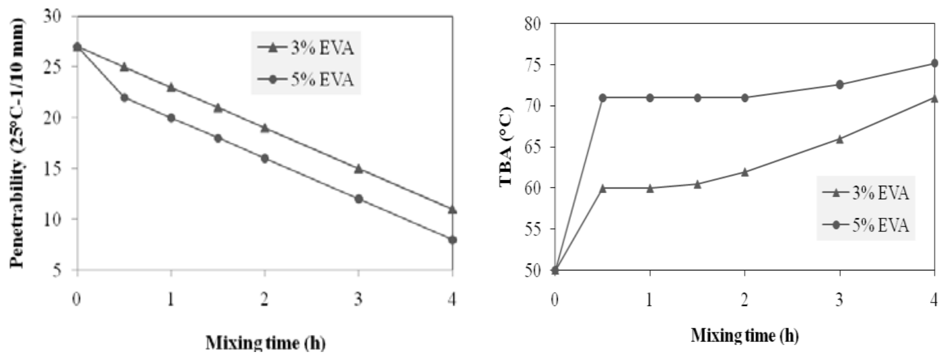


FIGURE 1. Evolution of penetrability and softening point according to time of malaxation

The decrease in penetration as a function of mixing time is linear (R^2= 1) at 2 (1/10mm) per half hour from the first 30 minutes of mixing

The softening point increases rapidly during the firsthalf hour at a rate of 20% for the mixture to 3% and 42% for bitumen at 5% EVA.

For both mixtures, 5% and 3%, there is a stagnation of the softening point bearings respectively 3 hours and 1 hour. This shows that the dispersion of polymer in bitumen takes some time depending on the content of EVA. Indeed, during this time the shear rate is not effective. This increase in softening point is favorable against the permanent deformations especially rutting [12]. These results show that the consistency of the binder-EVA evolves according to theamount of plastomer introduced. Indeed, at fixed mixing time, the consistency of 5% blend is harder than 3% of EVA. This trend is evident from the first half hour.

Figure 2 shows the ductility at 25 C° in different mixtures. 5% asphalt-EVA shows a sharp decrease in ductility of up to 1 hour mixing. Ductility varies linearly, reaching a value of 6.5 cm, making the mixture more sensitive to the tensile strength. The ductility of the mixture (3% -2 hours) decreases linearly up to 2 hours of mixing then it increases to a value of 17 cm, which contribute to the tensile strength.

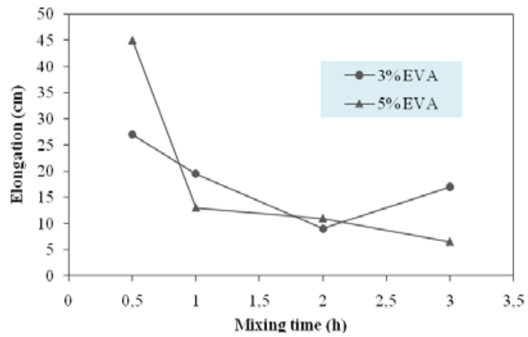
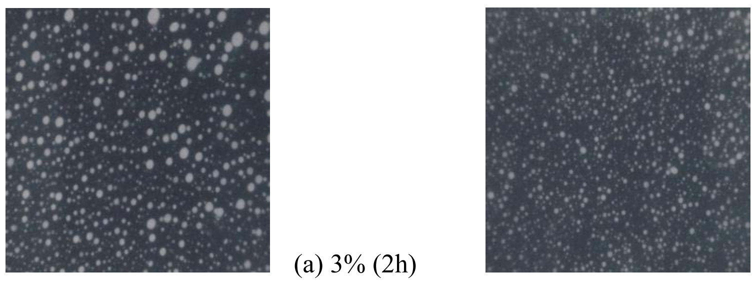


FIGURE 2. Ductility EVA blends

Figure 3 shows the dispersion of modifier in bitumen 40/50. The best microstructures are obtained for 3% of EVA mixed during 2 hours and for 5% of EVA mixed during 4 hours and with a finer structure for the 5%.



(a) 3% (2h) (b) 5% (4h)

FIGURE 3. Microstructure of EVA-bitumens EVA.

The evaluation of the storage stability estimated by ΔSP. The most stable mixtures, for the three contents of EVA, are obtained for a mixing time 2 hours (3%) and 4 hours (3 and 5%) whose ΔSP is lower than the limit of 2,5 °C.

Marshall Quotient

The values of the Marshall quotient (MQ) were calculated in order to evaluate the resistance of the modified bituminous concrete. A higher value of the quotient indicates than the mixtures are more resistant to the permanent deformations [13]. The evolution of the quotient according to mixing times is presented on figure 4.

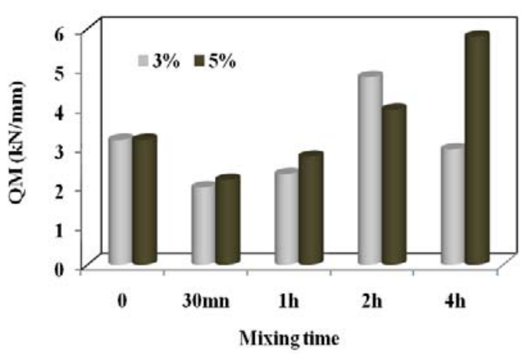


FIGURE 4. Marshall quotient for 3% and 5% of EVA according to the time of malaxation

The bituminous concrete containing modified bitumen with 3% of EVA reaches the maximum value of the QM for 2 hours compared to the reference bituminous concrete. That manufactured with the binder with 5% of EVA presents a maximum Marshall quotient for the modified binder mixing during 4 hours.

Indirect Tensile Strength

The indirect tensile strength was estimated for the two optimal formulas reserves from the Marshall test for an average temperature of service of 25°C. Figure 5 shows that resistance is improved for the two formulas, 3% (2h) being the best.

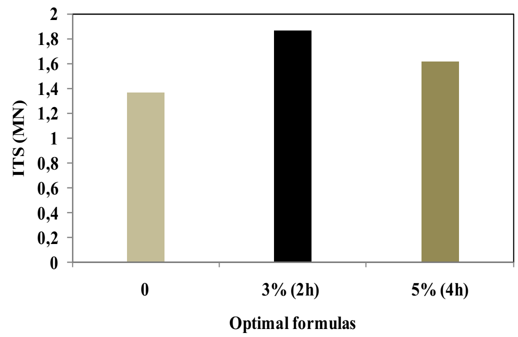


FIGURE 5. Indirect tensile strength

CONCLUSION

This study consists of the improvement of a bituminous concrete having a low resistance to the permanent deformations. The adopted approach is the modification by a plastomer like EVA. This work was access on the determination of the mixing time of bitumen modified to 3 and 5% of EVA by improving the mechanical performances of the bituminous concrete. The results obtained showed that the modification of the bitumen with the EVA is characterised by a reduction in the penetrability and an increase of the softening point, thus decreasing thermal susceptibility. The study of the mechanical behavior of the bituminous mix showed that best resistances to the permanent deformations at the high temperatures of service are obtained with 5% of EVA (4h) and 3% of EVA (2h). This is confirmed by the behavior with the average temperatures of service (25°C) for the two formulas.

The analysis of the microstructure confirms these results by the very good dispersion of polymer in the bitumen for the two formulas. Nevertheless, like the binder with 3% (2h) is not storable, we deduce that the binder with 5% of EVA (4h) is optimal.

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